Annual Fermilab Users' meeting June 2002

FNAL Theory Report

Ulrich Nierste
Fermilab

Outline

1. People and Research
2. Selected Research Topics
3. Summary

1. People and Research

Theoretical Physics Department Personnel 2001/2002

Scientists(11)
Bill Bardeen
Marcela Carena
Estia Eichten
Keith Ellis
Walter Giele
Chris Hill
Andreas Kronfeld
Joe Lykken
Paul Mackenzie
Stephen Parke
Chris Quigg

Associate Scientists(1)
Ulrich Nierste

Frontier Fellows(5)
Mariano Quiros (2001)
Alexei Smirnov (2001)
Ken Lane (2002)
Steve Gottlieb (2002)
Ulrich Baur (2002)

Dist. Guest Scientists(1)
Boris Kayser

Guest Scientists(3)
Alex Kagan
Sandra Padula,Prem Srivastava

Research Associates(8)

G. Barenboim	Andre DeGouvea	Massimo Di Pierro
Adam Leibovich	Heather Logan	David Rainwater
Zack Sullivan	Jing Wang	

Users

C. Albright (NIU)	J. Rosner (UC)
Y. Keung (UIC)	A. El-Khadra (Illinois)
S.P. Martin (NIU)	Ulrich Baur (Buffalo)

Current Research

Lattice gauge

Bardeen, Di Pierro, Eichten, Mackenzie, Kronfeld

Supersymmetry

Carena, Logan, Nierste, Rainwater

Perturbative QCD

Ellis, Giele, Leibovich, Parke, Sullivan

Flavor Physics

Bardeen, Leibovich, Nierste

Higgs Physics

Ellis, Logan, Nierste, Parke, Rainwater

Neutrino Physics

Barenboim, DeGouvea, Kayser, Parke

String Theory, D-branes, Extra dimensions

Carena, Lykken, Wang, Hill

Model building

Hill, Wang

Personnel Changes

- Outgoing Post-docs (Fall 2002)
  Andrea Romanino, Massimo Di Pierro, Heather Logan, David Rainwater, Jing Wang

- New Post-doc Hires (Fall 2002)
  Ayres Freitas (DESY): supersymmetry, electroweak radiative corrections
  Ulrich Haisch (TU Munich): B physics, radiative corrections
  Okamoto (KEK): lattice gauge theory
  Eduardo Ponton (Yale): supersymmetry, model-building
  Tim Tait (Argonne): collider physics, supersymmetry

- Associate Scientist Martin Schmaltz: left for BU

- New Associate Scientist Hires (2002)
  Ulrich Nierste (01/2002): B physics, supersymmetry
  Bogdan Dobrescu (07/2002): model building, collider phenomenology
  Yasunori Nomura (10/2002): model building

2. Selected Research Topics

Monte Carlo for Femtobarn processes

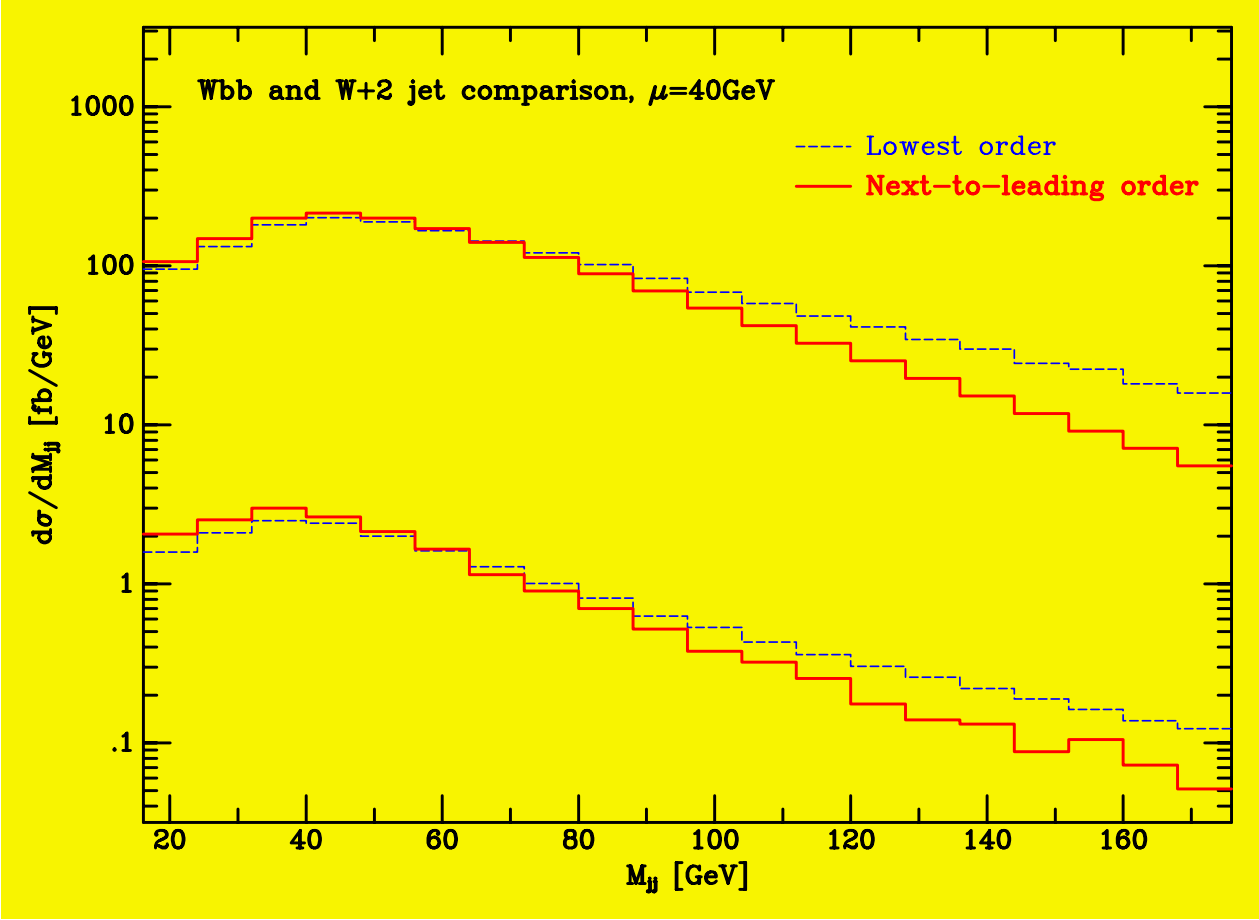
Campbell, Ellis

MC for background and signal processes for Higgs search at the Tevatron/LHC

- NLO QCD corrections are included.
- Study many processes in a common framework so that comparisons are possible.
- Interesting decays of the Z, W and H are included.

Included at NLO	
$p\bar{p} \to W^{\pm}/Z$	$p\bar{p} \to W^{+} + W^{-}$
$p\bar{p} \to W^{\pm} + Z$	$p\bar{p} \to Z + Z$
$p\bar{p} \to W^{\pm}/Z + H$	$p\bar{p} \to W^{\pm}/Z +$ 1 jet
$p\bar{p} \to W^{\pm} + g^{\star}(\to b\bar{b})$	$p\bar{p} \to Z + b\bar{b}$
$p\bar{p} \to W^{\pm} +$ 2 jet	$p\bar{p} \to Z +$ 2 jet
$p\bar{p} \to H$	

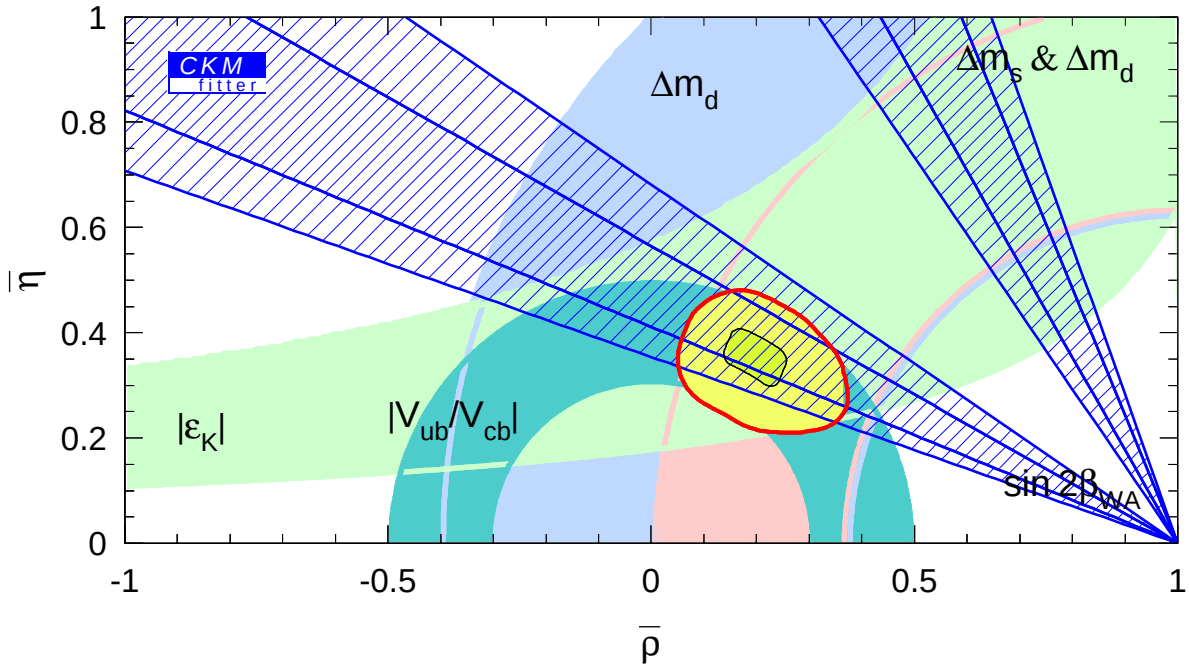
$W + b\bar{b}$ vs. $W + 2$ jets



- Plotted as a function of M_{jj} the two jet mass
- $\mu = 40$ GeV
- Rates for W+2 jets (upper curves) and $Wb\bar{b}$ (lower curves)

$B-\overline{B}$–mixing

The information on CP violation is encoded in the CKM unitarity triangle (UT):



Many measurements, mostly from B physics, contribute to our knowledge of the UT. Theory uncertainties from hadronic parameters, which are hard to compute, are often larger than experimental errors.

From $B_d-\overline{B}_d$–mixing find the mass difference

$$\Delta m_{B_d} \quad \propto \quad \left|V_{tb}V_{td}^*\right|^2 \widehat{B}_d f_{B_d}^2$$

$\Rightarrow$ information on $|V_{td}| = A\lambda^3\sqrt{(1-\overline{\rho})^2+\overline{\eta}^2}$.

But the uncertainty in the hadronic parameter is large:

$$f_{B_d}\sqrt{\widehat{B}_d} \quad = \quad (230 \pm 40) \text{ MeV}$$

The Beast

b-quark

Hadronic physics

The upcoming measurement of $B_s - \overline{B}_s$–mixing will substantially improve our knowledge of the unitarity triangle:

$$\frac{\Delta m_{B_d}}{\Delta m_{B_s}} = \left|\frac{V_{td}}{V_{ts}}\right|^2 \frac{1}{\xi^2}$$

$$\xi = \frac{f_{B_s}\sqrt{\widehat{B}_s}}{f_{B_d}\sqrt{\widehat{B}_d}}$$

In the $SU(3)_F$ limit the hadronic factor ξ equals 1. The calculation of $\xi - 1$ on the lattice involves an unphysically large down quark mass and the result must be extrapolated down to the physical mass (chiral extrapolation).

The conventional linear extrapolation gave $\xi = 1.15 \pm 0.05$. A new extrapolation taking care of logarithms known from chiral perturbation theory gives:

$$\xi = 1.32 \pm 0.10$$

Kronfeld, Ryan

Lattice QCD

Bardeen, Eichten, Di Pierro, Kronfeld, Mackenzie, Simone

New Computing facilities for lattice QCD: PC clusters. Space-time is described by discrete lattice, each PC node is responsible for a portion of the lattice, PC's are connected by fast switches.

Development of software and hardware infrastructure for US lattice QCD is currently being funded by DOE SciDAC, with hardware at three main centers: Fermilab, JLab, (clusters) and BNL (QCDOC).

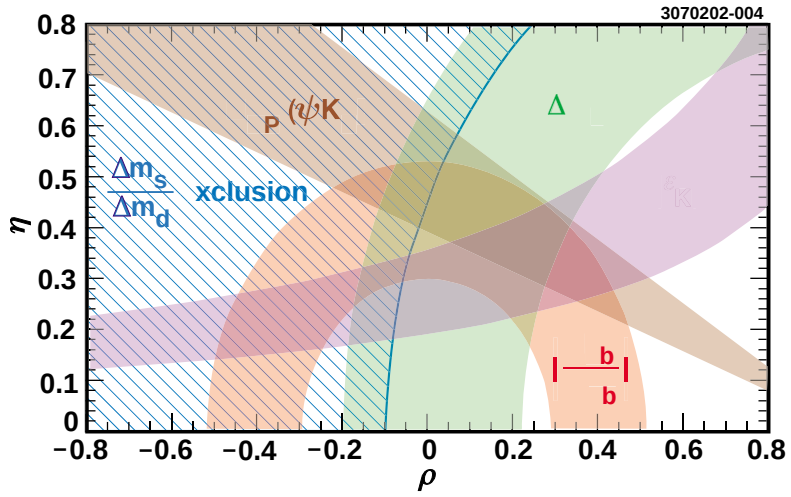
Fermilab clusters in New Muon Lab operated on behalf of Fermilab theorists and outside users, including MILC and Cornell collaborations.

- Now: 80 nodes. (Twice the power of ACPMAPS, ACPMAPS is turned off.)
- This year: $\rightarrow$ 256 nodes.
- 2003: $\rightarrow \sim$512 nodes.

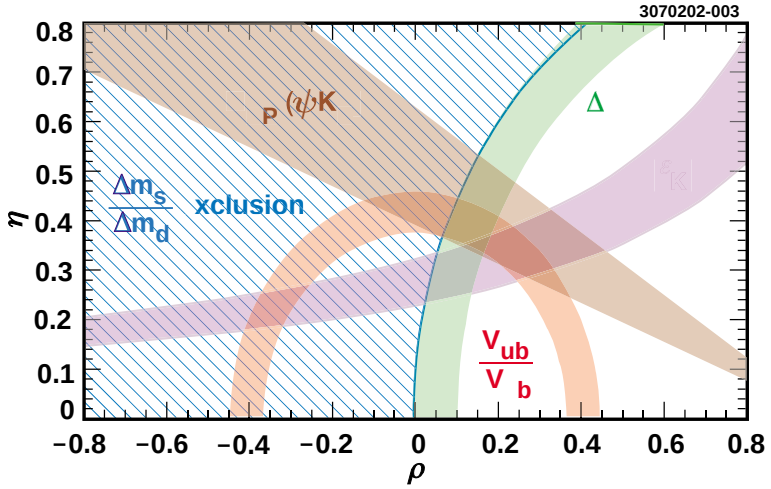
Physics goal:

Reduction of hadronic uncertainties in key quantities of charm and bottom physics.

Current uncertainties from theory and experiment:



Future projection using current experimental uncertainties, but theory uncertainties of 3%:



(Patterson, Cornell)

Only uncontrolled error in previous calculations (quenched approximation) will be removed in current calculations.

Current priority at Fermilab:
f_D, f_{D_s}, $D \to \pi l \nu$, $D \to K l \nu$, beat CLEO-c.

Supersymmetry and Rare B Decays Dedes,Dreiner,U.N.

Today the rare B Decay $B \to X_s\gamma$ gives valuable information on the supersymmetric parameter space.

Rising star: $B_s \to \mu^+\mu^-$ (yet unmeasured).

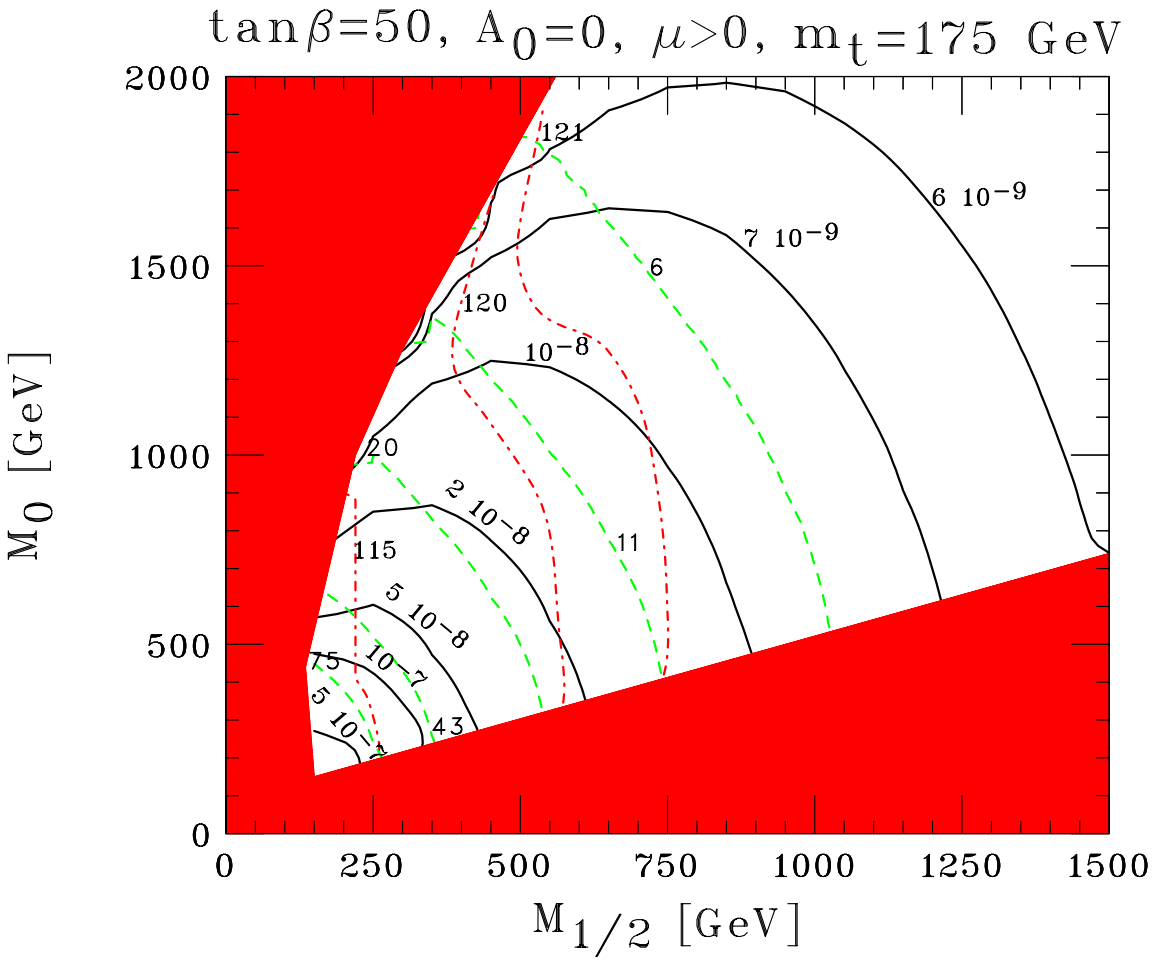
Important parameter: $\tan\beta =$ ratio of the two Higgs VEVs.

$Br(B \to \ell^+\ell^-)$

- probes the large $\tan\beta$ region better than any other B physics observables, with a possible enhancement over the SM by a factor of up to 1000, since $Br(B \to \ell^+\ell^-) \propto m_b^2 m_\ell^2 \tan^6\beta$.
- is most sensitive to effects from non-standard Higgs bosons,
- probes SO(10) GUT theories best,
- probes minimal supergravity scenarios (mSUGRA) through correlations with $(g-2)_\mu$ and the lightest Higgs boson mass,
- complements Tevatron searches for charginos/neutralinos through trilepton events.

mSUGRA: 5 parameters M_0, $M_{1/2}$, $\tan\beta$, A_0 and sgn μ defined at the GUT scale.

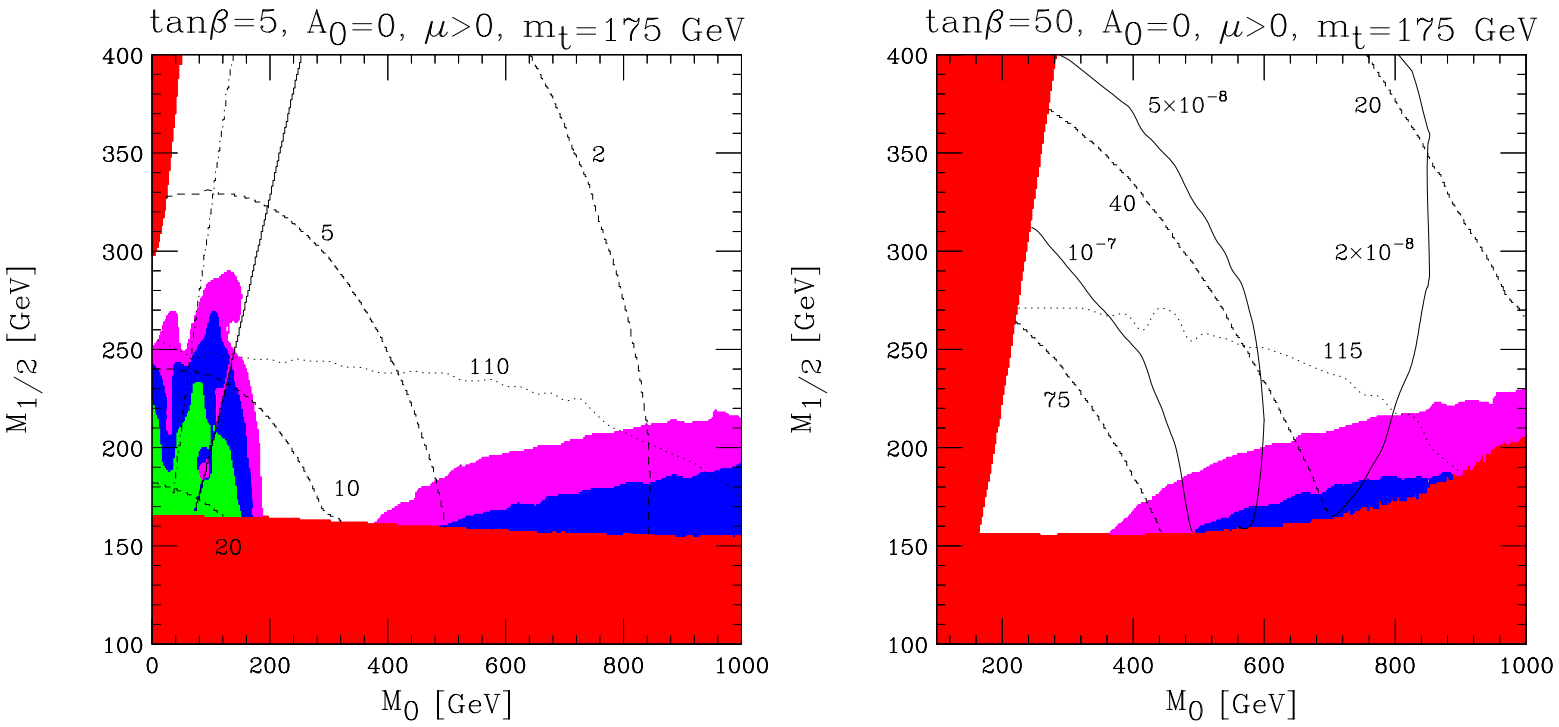
In mSUGRA there is a nice correlation of $Br(B_s \to \mu^+\mu^-)$ with the lightest Higgs boson mass and with $g-2$:



Any measurement of $Br(B_s \to \mu^+\mu^-)$ implies a useful upper bound on the lightest Higgs boson mass.

Trilepton Events and $Br(B_s \to \mu^+\mu^-)$

Dedes,Dreiner,U.N.,Richardson



Tevatron 5σ reach in the trilepton channel in the $M_0 - M_{1/2}$ plane for the mSUGRA scenario for small $\tan\beta = 5$ (left) and large $\tan\beta = 50$ (right) and $A_0 = 0$, $\mu > 0$ and $m_t = 175$ GeV. Magenta: $30 fb^{-1}$, blue: $10 fb^{-1}$, green: $2 fb^{-1}$. Solid contour (only for $\tan\beta = 50$): prediction for the $\mathcal{B}(B_s \to \mu^+\mu^-)$.

Report: *B physics at the Tevatron – Run II and Beyond*

Two workshops exploring the opportunities for CDF, D0 and BTeV were held at Fermilab in 1999 and 2000. The workshop report is now available (hep-ph/0201071).

- 553 pages
- 9 pages of index
- most up-to-date overview on B physics
- covers CP violation, mixing, lifetimes, rare and semileptonic decays, spectroscopy, production and fragmentation. . .

Summary

- The Theoretical Physics Department is both in touch with the experimental program of the lab and the frontiers of theoretical particle physics: perturbative QCD, lattice QCD, supersymmetry, B physics, ν physics, Higgs physics, collider physics,. . .
- Fermilab is well integrated into the worldwide theory community with fruitful cooperations and scientific exchange, and it attracts leading experts as post-docs, guest scientist and visitors.
- I have presented several examples of recent theory activities:
  - NLO Monte Carlo for boson(s)+jet(s) production,
  - efforts in lattice QCD to reduce uncertainties in charm and bottom physics,
  - interplay of B physics and particle searches to study supersymmetry and
  - the report
    B physics at the Tevatron – Run II and Beyond.